Appendix C: Merged Failure Data

C-1. Description

It is necessary to acquire mechanical and electrical equipment failure data specific to navigation lock and dam equipment to better represent the reliability models. Accumulated data will be analyzed to determine the failure rates that are experienced for applicable mechanical and electrical equipment.

C-2. Equipment Failure Survey

An equipment failure survey Internet Web site was developed as the means to acquire the necessary mechanical and electrical equipment failure data from across the United States. The survey format is currently located on the Internet. The survey Web site homepage is shown in Figure C-1. The survey web page is included in Figure C-2. Survey access may be obtained by logging in and creating an account. The user must create a password when creating the account, and then once the account has been created, the user may log in any time. For each subsequent login, repetitive information will automatically reload, and the user need only input the failure data itself.

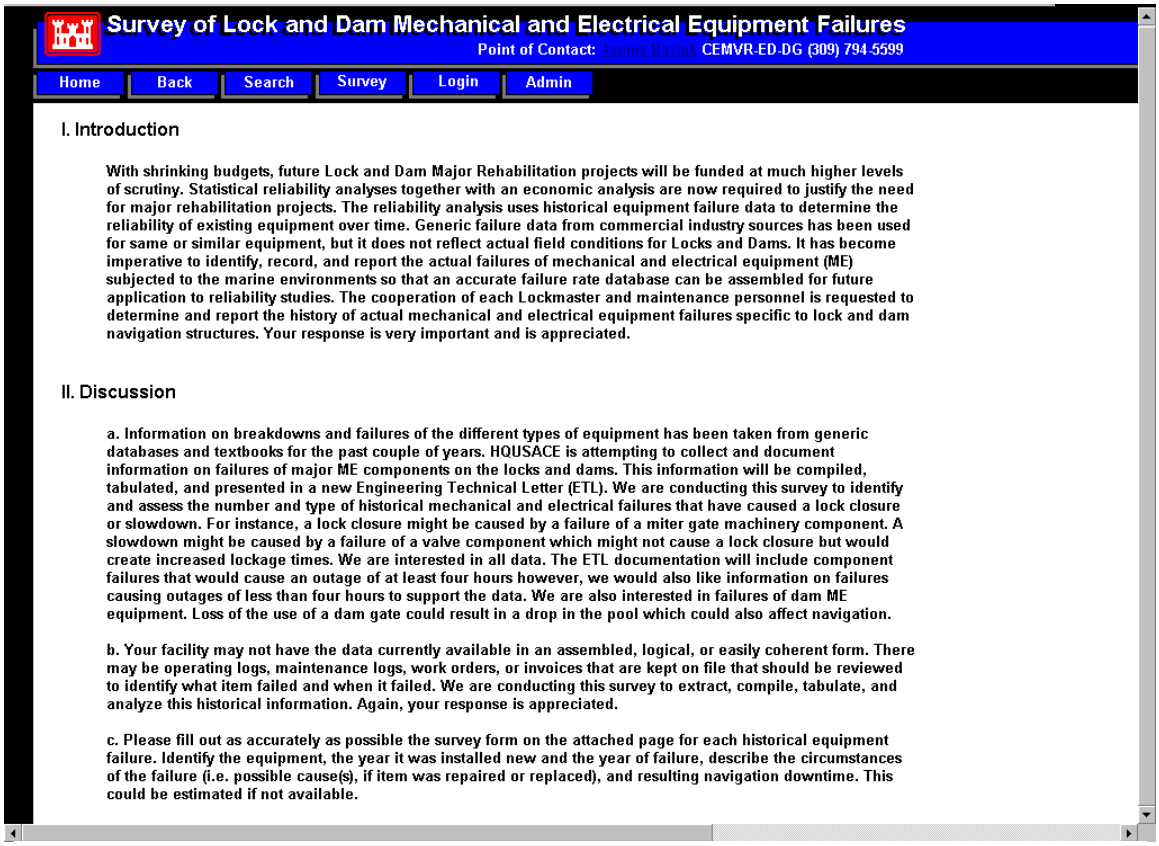

Figure C-1. Failure Survey Internet Homepage. http://www.mvr.usace.army.mil/failuredata/

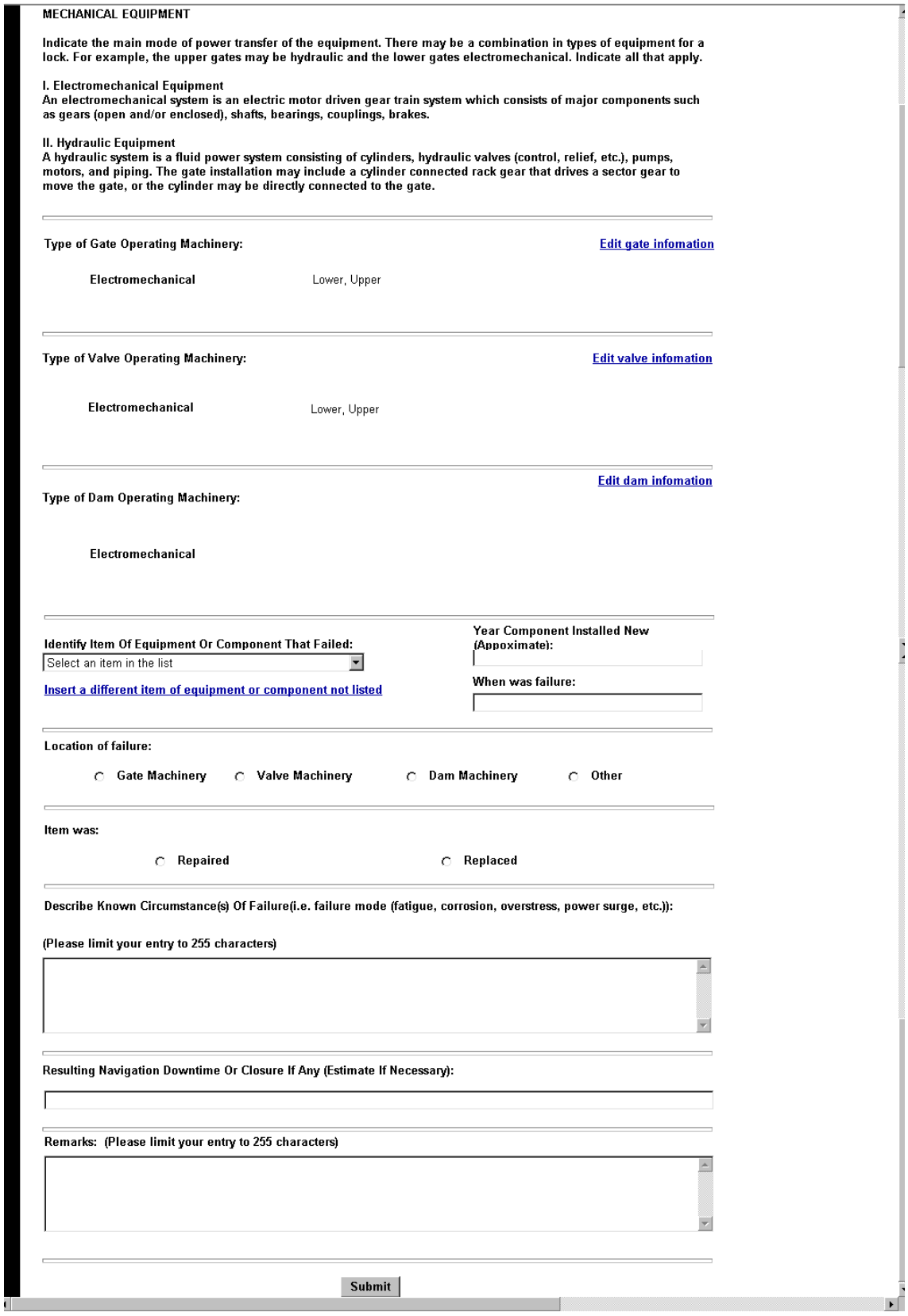

Figure C-2. Mechanical and Electrical Equipment Failure Survey Internet Page

C-3. Processing Data

The accumulated survey information is gathered electronically and stored to a failure database. The failure data entered to date was reviewed and processed for incorporation into this appendix and to provide actual data for mechanical and electrical equipment in use at navigation locks and dams. The database was manually manipulated by the process shown in the flowchart in Figure C-3. It was found during the process that some variations of entries had been entered. Some of the equipment did not apply or there were errors in the entries. Errors or nonapplicable components that were detected were either corrected or the data were not used.

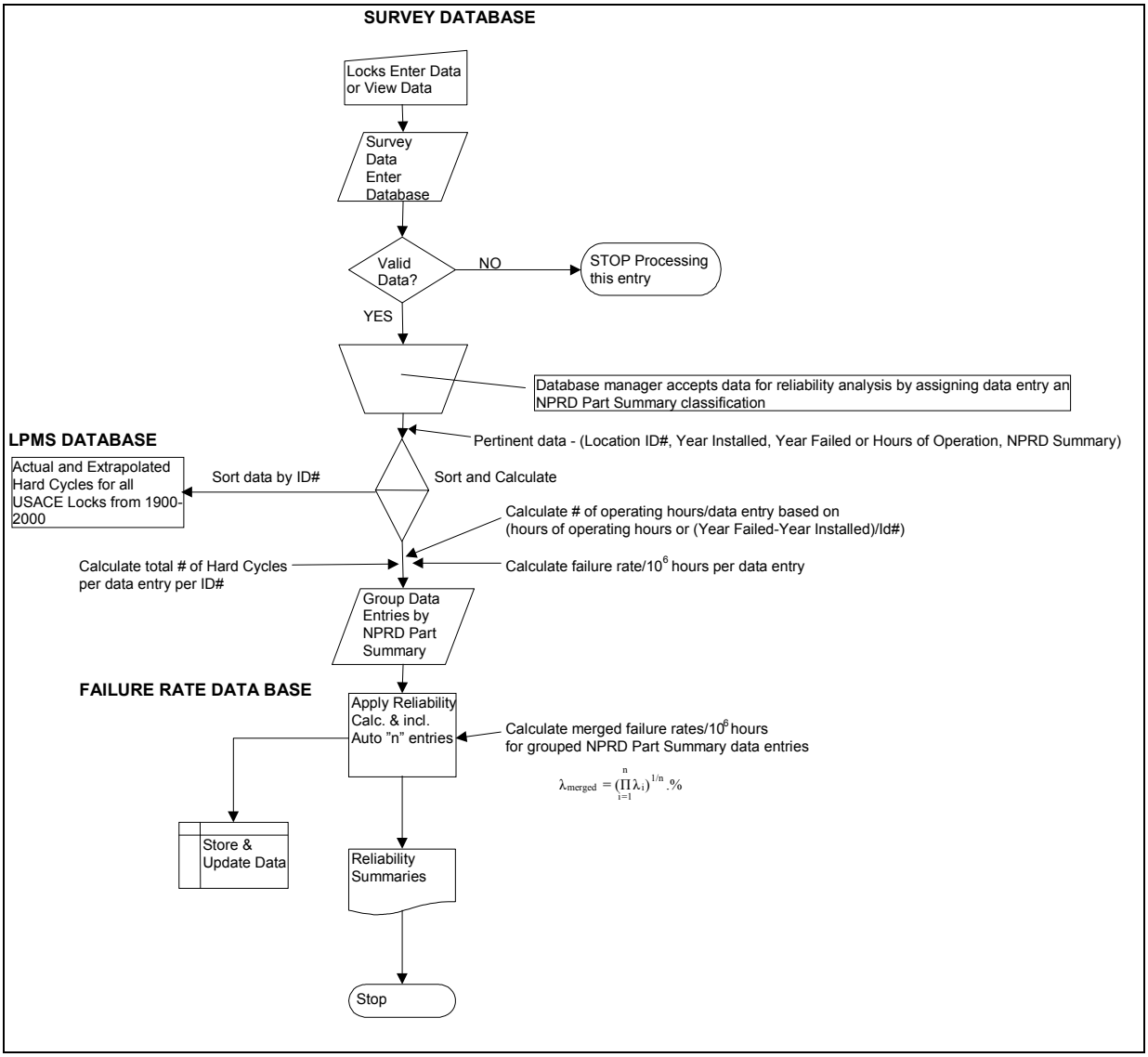

Figure C-3. Failure database analysis flowchart

C-4. Merged Failure Data

The data for individual components were grouped according to methods used and published by the Reliability Analysis Center (1995). The following equation from Reliability Analysis Center (1995) was used to merge the individual failure entries:

$$\lambda_{merged} = \left(\prod_{i=1}^{n} \lambda_i \right)^{1/n} * (\%) \qquad \text{(C-1)}$$

where

λ_{merged} = a summary failure rate derived from several constituent data source individual failure rates

n = number of records having failures

λ_i = individual failure rate from each source having failures. Individual failure rates were calculated by using a single failure divided by the total number of operating hours for that component

% = percentage of total operating hours associated with data entries having failures to the total operating hours of entries without failures. Percentage for Corps analysis was taken to be 100 percent since all data entries had failures and information related to the overall population and total number of operating hours for the population is unknown

The merged failure data are shown in Table C-1.

CAUTION: The resulting merged failure rates have inherently high variability and more closely represent worst-case failure rates. Real failure rates will be less than those presented. As more data are gathered from occurred failures, the merged failure rates will more closely approximate the real failure data.

Table C-1
Merged Failure Rates

U.S. Army Corps of Engineers Part Summary	Merged Failure Rate per 10^6 Operating Hours	Failures Analyzed
Bearing, Ball, Roller	216.7	5
Bearing, Sleeve	140.9	1
Bolt	69.8	8
Bolt, Anchor	67.8	2
Brake, Electromechanical	289.1	8
Brake, Shoe	3809.0	1
Bus, Connection	374.9	1
Bushing, Cable, Electrical	225.0	1
Bushing, Sleeve	72.4	8
Bushing, Sleeve, Pressed	180.6	1
Cable, Electrical	2482.6	1
Cable, Electrical Lead, Power	47.1	2
Cable, Electrical Lead, Utility 480V	183.6	2
Cable, Wire Rope	228.9	6
Chain, Hoisting, Bicycle Type	70.4	1
Circuit Breaker	127.3	6
Clutch	329.6	1
Clutch, Friction, Power Transmittal	446.4	2
Coil	1624.6	2
Control Assembly, Electrical	70.4	3
Control Panel	117.3	1
Control Panel, Generator	442.1	1
Coupling, Rigid	57.5	1
Coupling, Shaft	75.9	3
Coupling, Tube, Hydraulic	5482.3	2
Drum, Wire Rope	173.6	1
Electrical Motor, AC	296.6	7
Electrical Motor, AC, Starter	234.8	5
Fitting, Hydraulic	1826.2	1
Gauge	123.3	2
Gear Assembly	3809.0	1
Gear, Spur	70.4	1
Hose, Hydraulic	180.6	1
Motor, Selsyn	208.7	4
Nut, Split	2379.1	1
Pin, Mechanical, Gudgeon	94.7	1

(Continued)

Table C-1 (Concluded)

U.S. Army Corps of Engineers Part Summary	Merged Failure Rate per 10^6 Operating Hours	Failures Analyzed
Piston, Hydraulic, Rod	70.7	2
Programmable Logic Controller	216.8	2
Pump, Hydraulic	623.5	3
Receptacle, Electrical	433.4	1
Relay	238.2	3
Relay, Contact, Brake	89.0	1
Relay, Contact, Signal	89.0	1
Roller	122.6	2
Seal	295.5	20
Seal, Oil	149.7	3
Seal, O-Ring	89.0	1
Seal, Packing	94.5	2
Shaft, Power Transmittal	62.6	1
Solenoid, Assembly	125.0	3
Solenoid, Coil	227.8	3
Solenoid, Coil, Brake	60.7	2
Switch	237.8	3
Switch, Control	180.7	6
Switch, Control, Selector	307.9	1
Switch, Interlock	329.6	1
Switch, Limit	405.9	21
Switch, Limit, Rotary	298.1	7
Switch, Micro	142.0	2
Switch, Transfer, Automatic	139.8	4
Tubing, Hydraulic	129.2	2
Valve, Hydraulic, Solenoid	1826.2	1
Valve, Pilot	142.0	1